Bi-directional Route Optimization in Mobile IP Over Wireless LAN

Chun-Hsin Wu*, Ann-Tzung Cheng, Shao-Ting Lee, Jan-Ming Ho and D.T. Lee

Institute of Information Science, Academia Sinica, Taiwan

{wuch, jahorng, kingking, hoho, dtlee}@iis.sinica.edu.tw

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Motivation

• To develop a mobile communication infrastructure that supports cost-effective wireless broadband access for Intelligent Transportation Systems.

• Have developed a regional guidance system at *Academia Sinica* as a testbed.
  - MobileIPv4
  - Outdoor Wireless LAN (802.11b)
  - GPS

Introduction
Mobile Networks for a Regional Guidance System

Requirements

- Visitors’ mobile nodes can request contents from ordinary Internet servers or local specific servers as usual.

- Local servers can deliver contents to both visiting mobile nodes and ordinary Internet users.
Mobile Networks for a Regional Guidance System (Cont.)

Observations

Client-server applications:
- A session is usually initiated by the client.
- The client usually requests contents from multiple servers of the same provider.
  - {www, gif, search}.yahoo.com

In a guidance system:
- HAs are outside and CNs are inside the mobile Intranet.
- Neighboring MNs of the same FA access similar location-based contents from the same or surrounding correspondent nodes.

Goals
- Reduce access latency for MNs.
- Reduce overhead for border router.

Introduction
Issues with Base MobileIPv4 (RFC2002/3220/3344)

Mobile IPv4
All packets sent to MN are intercepted by its Home Agent and then tunneled to MN.
+ Backward compatible with IPv4

- Triangle Routing Problem
  - Long delay for MN
  - Overheads for border router and HA

- Ingress Filtering Problem
  - Packets from MN can’t be directly sent to CN.
    - Topologically incorrect packets are dropped by the routers. (RFC2267)
Route Optimization and Reverse Tunneling

- **Route Optimization**
  + an Internet Draft solving *unidirectional* triangle routing problem (Johnson & Perkins), but requiring all CNs to maintain Binding Cache for each MN.

- **Reverse Tunneling**
  + RFC2344 solving ingress filtering problem, but creating “*reverse* triangle routing problem”
Proposed Bi-directional Route Optimization

- Route Optimization
  - transparency issue in CN
  => Packet Tunneling and de-tunneling are performed by Correspondent Agent.
    + Binding Cache

- Reverse Tunneling
  - “reverse triangle routing problem”
  => Packets from MN can be Directly Tunneled from FA to CA/CN.
    + Tunneling Cache

An entry indicates that a correspondent node or network supports tunneling.
Proposed Bi-directional Route Optimization (Cont.)

- Enhancements
  - Correspondent Agent
    - Binding Cache
  - Direct Tunneling
    - Tunneling Cache
  - Subnet-based Route Optimization
  - Binding Optimization
Subnet-Based Route Optimization

- Reuse CA-FA tunnel of CN₁-MN₁:
  1) Sending packets from MN₁ to CN₂
  2) Sending packets from CN₂ to MN₁
  3) Sending packets from MN₂ to CN₁ or CN₂
  (Setup still needed for CN₁ or CN₂ to MN₂)
  No control messages required to setup additional MNₓ-CNᵧ tunnels for cases 1-3.
- Cache entries reduction

If no tunnel reuse:
- CN₁: \{MN₁, FA\}, \{MN₂, FA\}
- CN₂: \{MN₁, FA\}, \{MN₂, FA\}
- MN₁: \{CN₁, CA\}, \{CN₂, CA\}
- MN₂: \{CN₁, CA\}, \{CN₂, CA\}

If tunnel reuse:
- CA: \{MN₁, FA\}, \{MN₂, FA\}
- FA: \{SubnetCX, CA\}
Binding Optimization for Fast Handoff

- In addition to HA, FA can also send Binding Update message directly to particular CAs.
  - Reduce the handoff delay to update the binding to MN without going through HA.
- Support backward-compatibility with the base mobile IP.
Simulation

- Each MN will connect with $n$ of CNs, evenly distributed among $m$ of CAs.
  \[ n = |CN| = 20, \ m = |CA| = 1 \ldots 20 \]
- There are totally $o$ of MNs, evenly distributed among $p$ of FAs initially.
  \[ o = |MN| = 500, \ p = |FA| = 5 \]
- Each MN has a probability of $q$ to perform handoff every minute, where $q = 0.2$
- Each simulation runs for 1 hour. The lifetime for each entry in the binding cache is set as 5 minutes in IETF route optimization.
- The total number of control messages includes Binding Update, Binding Acknowledge, Binding Warning, Registration Request to FA/HA and Registration Reply from FA/HA.
- Refer to Vadali, et al., VTC 2001 Spring.
Simulation Result: Total # Messages

Total numbers of control messages after 1 hour:

*IETF RO  (461492)
+Agent-based RO  (43101)
Subnet-based RO  (35668)

Total handoff  (5943)

- *IETF RO is subject to expiration.
- 5943 * 4 Messages per handoff
- \((n,m,o,p,q) = (20,1,500,5,0.2)\)
Control Messages for Each Approach

- **IETF RO: 504,000**
  - Registration: 24,000
    - 6000 Handoffs * 4 Messages (Reg/Reply between MN/FA/HA)
  - Binding Update: 240,000
    - 6000 Handoffs * 20 |CN| * 2 Messages (Update/Ack)
  - Expiration: = 240,000
    - 500 |MN| * 20 |CN| * 12 Times * 2 Messages (Update/Ack)

- **Agent-based RO: 42,000**
  - Registration: 24,000
  - Binding Update: 18,000
    - 6000 Handoffs * 1 |CA| * 3 Messages (Warning/Update/Ack)

- **Bi-directional RO: 36,000**
  - Registration: 24,000
  - Binding Update: 12,000
    - 6000 Handoffs * 1 |CA| * 2 Messages (Update/Ack)
Simulation Result: $|CA| = 1$

All CNs are in the same CA.

- IETF RO:
  depending on $|CN|$
- Agent-based RO / Subnet-based RO:
  depending on $|CA|$

$(n,m,o,p,q) = (|CN|, 1,500, 5, 0.2)$
Simulation Result: $|\text{CN}| = |\text{CA}|$

One CN per CA:
- All depend on $|\text{CN}|$, and the number of messages required during handoff.

$$(n,m,o,p,q) = (|\text{CN}|,|\text{CN}|,500,5,0.2)$$
Simulation Result: $|\text{CN}|/|\text{CA}|=5$

- IETF RO: depending on $|\text{CN}|$
- Agent-based RO / Subnet-based RO: depending on $|\text{CA}|$

$(n,m,o,p,q) = (|\text{CN}|,|\text{CN}|/5,500,5,0.2)$
Control Messages at Border Router

Total numbers of control messages:
- IETF RO (382394)
- Agent-based RO (33185)
- Subnet-based RO (12674)

- *IETF RO is subject to expiration.
- 5943 * 4 Messages per handoff
- Registration messages and initial BU messages are required to all approaches.
- \((n,m,o,p,q) = (20,1,500,5,0.2)\)
Traffic Load at Border Router under Different Packet Sizes

TCP Server: CN
TCP Client: MN
CN2MN: data packets (64 kbps)
MN2CN: ACK packets (4 kbps)

Small packets need more packets, each has packet header overhead.

\[(n, m, o, p, q) = (20, 1500, 5, 0.2)\]

Simulation and Implementation
Traffic Load at Border Router under Different Uplink and Downlink Rates

- Higher uplink rates in IETF RO and agent-based RO cause higher overhead to the border router.

Simulation and Implementation

\[ 64 \text{ kbps} \times 500 \text{ MNs} \times 20 \text{ CNs} = 640 \text{ Mbps} \]

\[ (n,m,o,p,q) = (20,1,500,5,0.2) \]
Locations of Access Points

1. Main Gate
2. Computing Center
3. Institute of Physics
4. Fu Ssu-Nien Library
5. Institute of European and American Studies
6. Institute of Information Science
7. Center for Academia Activities
8. Institute of Statistical Science
9. Institute of Astronomy and Astrophysics
10. Institute of Molecular Biology

Simulation and Implementation
AutoPC Prototype

Single Board PC: 14.5cm * 10.2 cm
Compaq iPAQ H3630 PDA

Program size: 1.6 Mbytes

MPEG-4: 30 FPS on AMD K6-2/350 platform;
800 Kbps for CIF (352*288) resolution

MP3: 150 Kbps on 486 platform

Simulation and Implementation
Navigation Services

(a) 2-D view

(b) Bird’s eye view

(c) Location-based query

(d) Replaying previous traveling path

Simulation and Implementation
Audio and Video Streaming

MP3

MEPG-4

Simulation and Implementation
Conclusion

- Bi-directional route optimization is proposed to improve the routing efficiency of mobileIPv4 in a regional guidance system over wireless LAN.
  - Correspondent agent
  - Direct tunneling
  - Subnet-based route optimization
  - Binding optimization

- The proposed approach can reduce the access latency of mobile nodes and the overhead of the border router significantly.
  - Reduce the length of a routing path.
  - Reduce the traffic at the border router.